

Nanotribology and Surface Properties

Accurate adhesion and friction measurements at the nanoscale are emerging as critical issues in device industries and nanotechnology. Measurements characterizing nanometer-thick molecular assemblies and surface textures to control surface properties and to ensure reliability and durability are also needed. Working with device and magnetic storage industries and other agencies, we have designed and built instruments to meet these needs. These instruments are housed in NIST's new Advanced Measurement Laboratory. The facility features vibration isolation, class 1000 clean room standards, and temperature control.

Stephen M. Hsu

The nanotribology and surface properties project was initiated as a part of the MSEL Nanotechnology Initiative. The project aims to develop measurement capability for adhesion, friction, and surface forces at the nanoscale. We interact extensively with many industries and research centers in the U.S. and around the world to promote advances in measurement science and seek consensus standard harmonization in three areas: nanocontacts, nanolubrication, and surface texturing.

Nanocontacts

Adhesion and friction measurements at nanocontacts require accurate detection of normal and lateral forces at nanonewton levels. Scanning probe microscopes use sensitive cantilevers and laser diodes to detect these forces, but this approach introduces rotation of the tips and crosstalk among the xyz planes. To understand the influence of surface forces, many of which are functions of contact area, attention must be focused on determining the real area of contact.

To resolve some of the instrumental challenges, we have engaged instrument makers, such as Hysitron, Veeco, and others, to solicit their inputs and collaborations. At the same time, we have established our own capability in tip fabrication, cantilever spring constant calibration, and tip characterization. Three new instruments were successfully installed as a result of these collaborations: the NIST–Hysitron multiscale friction tester, the NIST nanoadhesion apparatus, and the first prototype of an interferometer microscope from Veeco. We are continuing to work with our partners to develop next-generation instruments as suggested by the Nanometrology Grand Challenges Workshop (NIST, January 2004).

The overall objective of the nanocontacts activity is to develop the constitutive equation of adhesion and friction including the various components of surface forces. With our new adhesion and nanofriction apparatus, we are quantifying the effects of plowing and electrostatic charge on measurements. We continue to work with our external academic partners (UC Berkeley, UC Davis, and Ohio State U) under the Nanotechnology Extramural Initiative to develop friction measurement via three approaches: friction measuring MEMS devices, AFM methods, and ultrahigh vacuum friction measurement. These efforts have been successful, and we have gained considerable understanding of how meniscus forces and electrostatic forces can exert significant effects on nanofriction measurements. A NIST special publication summarizing these findings is under preparation.

Nanolubrication

Molecular assemblies can be organized to impart hydrophobicity, anti-adhesion, and friction control characteristics on device surfaces. Supported by other agencies and the magnetic storage industry, this activity focuses on how to measure the effects of controlled composition and spacing on properties of nanometer-thick films. An ultrahigh vacuum scanning tunneling microscope-atomic force microscope was installed in May 2004 to provide imaging capability at the molecular level. A micro-tribometer was also developed to measure the durability of these films. The synchrotron facility operated by the Division's Characterization Methods Group at Brookhaven National Laboratory continues to be vital in characterizing these complex molecular mixtures.

Surface Texturing

Surface texture increasingly is being considered as a tool to control surface energy, polarity, adhesion, and friction. Supported by other agencies and industries, we are pioneering the use of specific surface features such as dimples, triangles, and ellipses at micro- and nanoscale dimensions to supplement molecular assemblies to control surface properties of surfaces. An international cooperative study under the auspices of International Energy Agency (IEA) is underway.

Contributors and Collaborators

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